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Outline

Effects of Non-stoichiometry and Microstructure on Thermal Diffusivities/Effusivities of Iron Oxide Scales Thermally Grown on Iron Substrates

Chapter 1 "Introduction"

This chapter explained the background and introduced the objectives of this thesis: to measure the thermal diffusivity of $Fe_{1-x}O$ scale without phase transformation at high temperature, and to investigate the effects of non-stoichiometry and microstructure on thermal properties of iron oxides.

Chapter 2 "Establishment of Measurement Technique of Thermal Diffusivity for Oxide Scale by Electrical-optical Hybrid Pulse-heating Method"

The electrical-optical hybrid pulse-heating method was established to measure the thermal diffusivity of $Fe_{1-x}O$ scale at high temperature without the effect of phase transformation of $Fe_{1-x}O$ to Fe and Fe_3O_4. $Fe_{1-x}O$ scale sample was indirectly and rapidly heated up to experimental temperature by Joule heating of the iron substrate, and laser flash method was subsequently conducted. Finally, thermal diffusivity of $Fe_{1-x}O$ scale was successfully obtained at 932 K. It was found that there is a suitable thickness range of $Fe_{1-x}O$ scale to determine the thermal diffusivity with high accuracy.

Chapter 3 "Measurement of Thermal Diffusivity of $Fe_{1-x}O$ Scale by Electrical-optical Hybrid Pulse-heating Method as a Function of Temperature"

Thermal diffusivities of $Fe_{1-x}O$ scale were measured at room temperature and high temperatures. The samples were prepared by oxidizing iron coupons in air, followed by removal of Fe_2O_3 and Fe_3O_4 layers on the outer surface of the oxide scale by sandblasting to remain 50 μm-thick $Fe_{1-x}O$ scales. Thermal diffusivity of $Fe_{1-x}O$ scale measured did not show obvious temperature dependence.

Chapter 4 "Distribution of *x* in $Fe_{1-x}O$ Scale and the Relationship between *x* Value and Thermal Effusivity of $Fe_{1-x}O$"

Since $Fe_{1-x}O$ scale grows by diffusion of iron ions from the substrate, there should be distribution in deficiency of Fe from $Fe_{1-x}O$/Fe interface to surface of the oxide scale. To investigate the effect of deficiency distribution on the thermophysical property, pulsed light heating thermoreflectance technique has been applied to measure thermal effusivity at a few 10-μm are with a depth of several micron meters. The thermal effusivity was measured at every 15 μm in the $Fe_{1-x}O$ scale from the surface. The measured result showed that thermal effusivity increased with decreasing deficiency.

Chapter 5 "Relationship between Microstructure and Thermal Effusivities of Iron Oxides"

The effect of microstructure on thermal effusivities of iron oxides has been investigated. Thermal effusivities were measured on $Fe_{1-x}O$, Fe_3O_4 and Fe_2O_3 scales, and sintered Fe_3O_4 and Fe_2O_3. The effects of microstructures on thermal effusivity are summarized based on the data measured: (1) long grain boundaries and micro cracks in the direction perpendicular to the heat diffusion direction have the greatest effect for lowering thermal effusivity; (2) tiny granular-type grains also decrease thermal effusivity in some degree; (3) micro cracks or grain boundaries parallel to heat diffusion distance have the smallest effect.

Chapter 6 "Effects of Non-stoichiometry and Microstructure on Thermal Diffusivities of Iron Oxide Scales"

In this chapter, a comprehensive discussion has been made for the effects of non-stoichiometry and microstructures on thermal diffusivity and the temperature dependence based on all the data measured in previous chapters. The thermal effusivities measured were converted into thermal diffusivity for the comparison. It was found that effect by microstructure is more significant than that by deficiency distribution in $Fe_{1-x}O$ scale from the data measured at room temperature. The thermal diffusivity of $Fe_{1-x}O$ scale is much smaller than those of NiO, MgO and CaO, and there was no significant temperature dependence in thermal diffusivity. These findings can be mainly caused by the effect of non-stoichiometry of $Fe_{1-x}O$ since the Fe ion defects in the $Fe_{1-x}O$ make the phonon mean free path shorter. The apparent thermal conductivity was estimated for a scale having a typical structure based on the thermophysical properties measured in this study.

Chapter 7 "Conclusions"

Non-stoichiometry is the most decisive factor affecting thermal diffusivity and its temperature dependence of $Fe_{1-x}O$ scale, by drastically decreasing phonon mean free path. The deficiency of iron decreases thermal diffusivity of $Fe_{1-x}O$; however, different x values do not change the thermal diffusivity largely, the effect of defficiency is smaller than those caused by different microstructures.